DEVELOPMENT OF CEMENT FOAMED-ASPHALT STABILIZED BASE WITH SLURRYED-CEMENT

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ABSTRACT

In Japan, maintenance and rehabilitation of asphalt pavements is even more necessary, as the stock of the pavements is increasing. Cement foamed-asphalt (CFA) stabilized base has frequently been constructed on-site, because it has moderate rigidity and flexibility for durability. However, cement that is spread on-site could scatter to spoil farm products around the roadside, if CFA stabilized base is constructed at farm roads, especially in a strong wind. So, to prevent such cement scattering, we have invented a construction method of CFA stabilized base with slurryed-cement, that is Slurryed-Cement Foamed-Asphalt (SCFA) stabilized base. In the invention, we have developed a machine (Slurry Machine) to spray slurryed-cement on-site, and constructed SCFA stabilized base with Slurry Machine at a yard for accelerated loading test. During construction at the test yard, no cement scattering was observed at all, and from results of the accelerated loading test, SCFA stabilized base is found to have superior durability.

1. OUTLINES AND ISSUE OF CFA STABILIZED BASE

CFA stabilized base, which includes cement and formed-asphalt as stabilizers, is a type of on-site recycling methods for asphalt pavements, and is well-known as specified in “Pavement Recycling Guide (February, 2008)” in Japan. CFA stabilized base moderately has both properties of rigidity with cement and flexibility with formed-asphalt to demonstrate superior durability.

On the other hand, there is an issue that cement spread on-site could scatter to harm environment around the construction site as shown in Photo-1. Although dust-inhibiting cement could be applied to control cement scattering, it is not able to stop cement scattering absolutely.

Photo-1. Cement scatting on a site.

2. DEVELOPMENT OF SCFA STABILIZED BASE WITH SLURRYED- CEMENT

We have invented the new construction method of SCFA stabilized base with slurryed-cement made of cement and water in order to stop cement scattering.

However, since some problems with slurryed-cement different from with general powdery cement are propounded, we have performed some laboratory tests, machine development to spray slurryed-cement and establishment of a construction process, and an accelerated loading test as following.

(1) Laboratory tests on Workable time of SCFA stabilized base

Since cement reacts with water to begin hardening, we should check workable time of slurryed-cement in a laboratory. [1]

(2) Development of Slurry Machine and establishment of construction process

Through construction of SCFA stabilized base, we have to spray a specified amount of slurryed-cement on-site quickly and uniformly, so we need to develop Slurry Machine to spray slurryed-cement and establish a construction process of SCFA stabilized base. [2]

(3)Accelerated loading test on durability of SCFA stabilized base

It has been confirmed from on-site search results that CFA stabilized base with general powdery cement has required durability. [3] However, durability of SCFA stabilized base with slurryed- cement has not been checked, so we should determine it with an accelerated loading test machine. Furthermore, during constructing of SCFA stabilized base in an accelerated loading test yard, we can check whether cement scatter or not. [4][5]

2-1 Laboratory test Results on Workable Time of SCFA Stabilized Base

(1) Workable time of slurryed-cement

At first, we have determined how a ratio of water and cement, the mixing method of slurryed-cement and the leaving time after slurryed-cement is made influence the strength of slurryed-cement after hardening. Workability (the flowing time through P-funnel) of slurryed-cement changes over the mixing time as shown in FIgure-1. The ratio of water and cement (W/C) has been decided to be 60 %, because workability at W/C 60 % is better than that at W/C 50 %, and almost same as one of slurryed-cement for semi-flexible pavements. We have adopted 292 rpm as the mixing speed from Figure-1, because the change of workability of slurryed-cement at 292 rpm is less than that at 146 rpm in case of W/C

60 % without the superplasticizer. Furthermore, in case that W/C is 60 % and the mixing speed is 292 rpm in Figure-1, workability of slurryed-cement with a superplasticizer changes less than without one, so the superpolasticizer makes workable time of slurryed-cement longer.

To determine change of the strength on slurryed-cement after hardening due to the mixing time, we have conducted flexure and compressive tests with specimens that of slurryed-cement mixed within 5 hours (curing time: 7 days, specimen size: 40x40x160 mm, W/C: 60 %, mixing speed: 292 rpm). The test results are shown in Figure-2. From these results, flexure strength meets the specification (2 MPa or more) in all mixing time, on the other hand compressive strength decreases over the mixing time to be less than the specification (from 10 to 29 MPa) after 5 hours. Therefore, workable time of slurryed-cement is expected to be about 4 hours from a viewpoint of both workability and strength mentioned above.

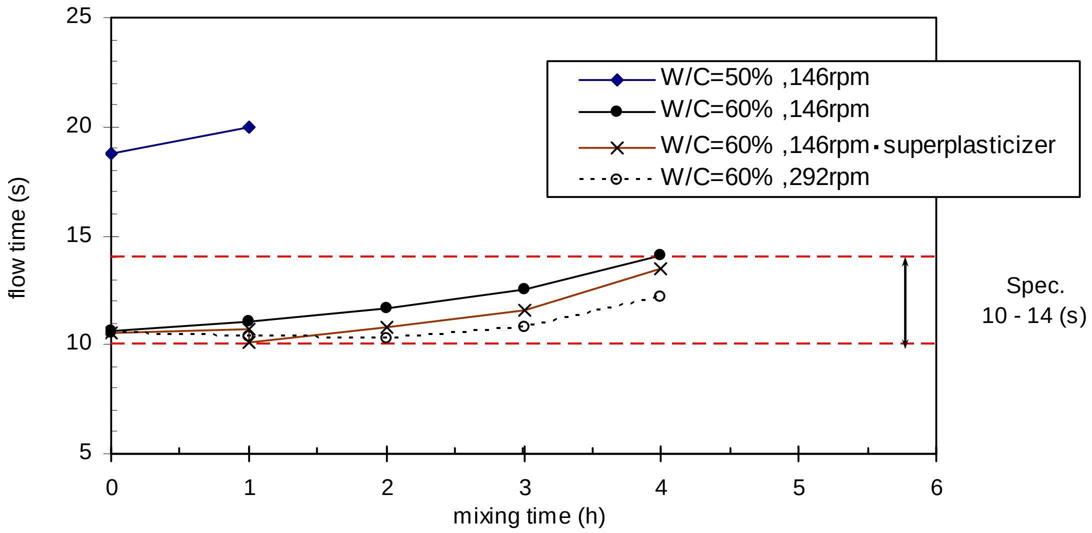

Figure-1. Workability change of slurryed-cement.

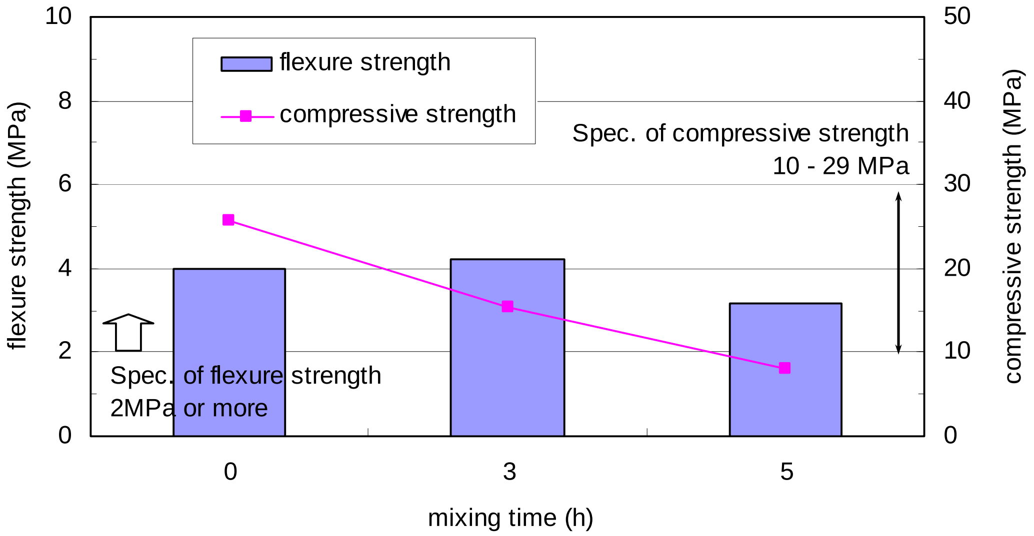

Figure-2. Strength change of slurryed-cement.

(2) Workable time of SCFA stabilized base

We have conducted mix design of CFA stabilized base using a granular base material with general grading. In the optimum mixing ration (4.0% of bitumen content, 2.5% of cement content). SCFA stabilized base specimens with slurryed-cement (W/C=60%) have been made at various time leaving the mixture non-compacted after mixing in order to determine change of the strength. Unconfined compressive strength of SCFA stabilized mixture at each leaving time changes as shown in Figure-3. Although the strength decreases as the leaving time passes, it is within the specification even after 5 hours mixing.

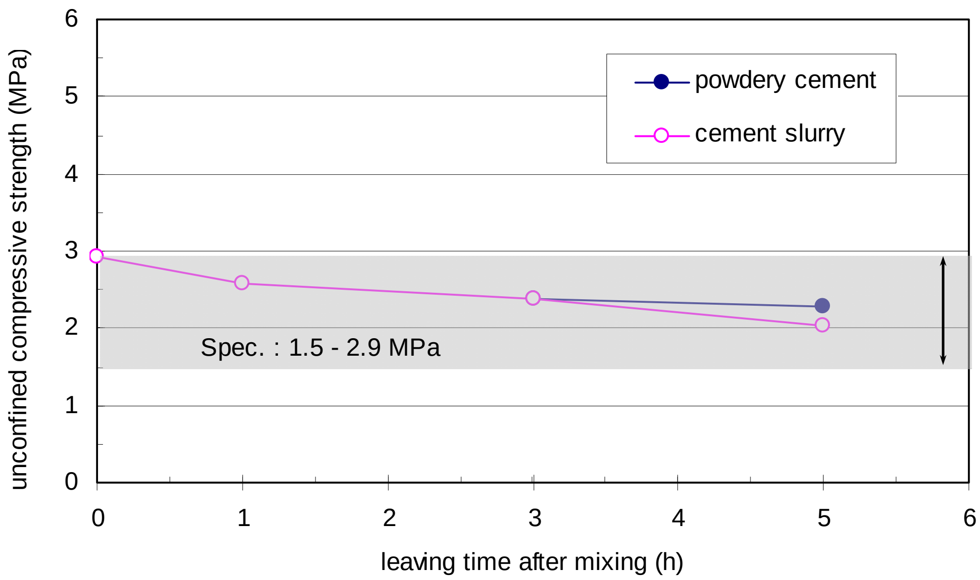

Figure-3. Strength change of SCFA stabilized base.

(3) Summary of workable time

As mentioned above, workable time both of slurryed-cement (W/C 60%) and SCFA stabilized base mixture are expected about 4 hours. Since these workable time exceed about 1 or 2 hours needed to construct CFA stabilized base in a general condition, we have determine that SCFA stabilized base is suitable to on-site construction. In addition, if slurryed-cement is mixing for a long time on-site, adding a superplasticizer into slurryed-cement can make its workable time longer.

2-2 Development of Slurry Machine and Establishment of Construction Process

(1) Development of Slurry Machine

Workability and strength of slurryed-cement change after mixing, so we have developed Slurry Machine spraying slurryed-cement on-site quickly, uniformly and automatically. The specification of Slurry Machine is listed in Table-1. The appearance and operating view of Surry Machine are shown in Photo-2 (a), (b), respectively. Slurry Machine has the following features; it has the storage tank equipped an agitator to mix slurryed-cement without significant change of workability; it has 4 nozzles to spray slurryed-cement uniformly at the rear of the machine; quantity of sprayed slurryed-cement is adjusted automatically according to machine's driving speed; it has some scarifiers that make ditches on a road surface in order to prevent sprayed slurryed-cement from flowing outside of the road.

Table-1. Specification of Slurry Machine.

	Item	Specification
Basic performance	Body length	7,080 mm
	Body width	2,500 mm
	Gross weight	10,300 kg
	Engine power	60 ps
	Driving speed	Max 7 m/min
Slurry equipment	Width for spraying	1,000 - 2,500 mm
	Number of spraying nozzles	4
	Control system for spraying	Automatic system according to driving speed
	Discharge capability of pump	Max 250 L/min
	Mixing speed	150 rpm
	Tank capacity	3.8m^3

Photo-2. Slurry Machine.
((a) Appearance, (b) Operating view）

(2) Establishment of construction process

The construction process is shown in Figure-4. After produced at a freshly mixed concrete plant, slurryed-cement is carried in an agitator truck to be discharged into the tank of Slurry Machine on-site.

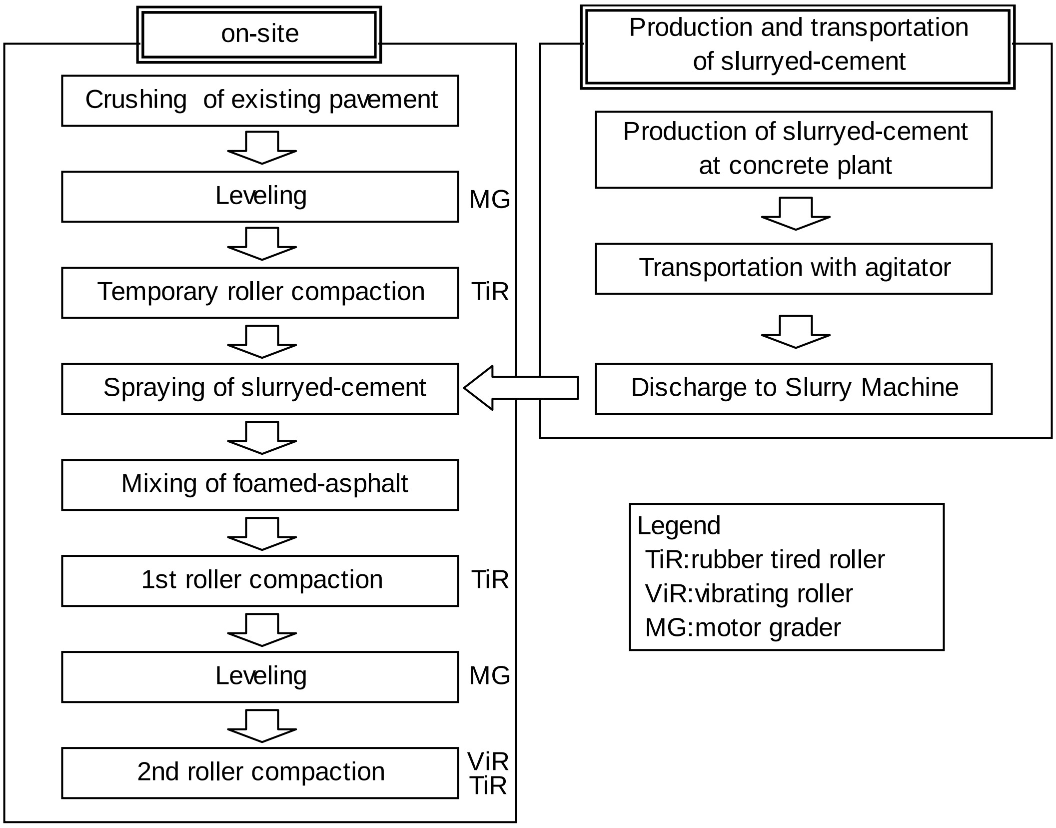

Figure-4. Construction process.

2-3 Evaluation results of durability of SCFA stabilized base

We constructed SCFA stabilized base in the accelerated loading test yard (shown in Photo-3) at Techno-center of KAJIMA ROAD Co., LTD. in Saitama prefecture, Japan in February 2006, and have evaluated durability of SCFA stabilized base using the accelerated loading test machine.

Photo-3. Accelerated loading test yard and machine.
((a) Panorama, (b) Loading equipment)

(1) Outline of test yard

In order to construct the pavement capable to bear the daily traffic volume N_3 (below 100 trucks / day), the existing pavement at the test yard was crushed and stabilized in 20cm thickness with the SCFA stabilization. The pavement cross sections of the test yard before, under and after construction are illustrated in Figure-5. After SCFA stabilized base was cured for 7 days, we loaded a 49 kN wheel on the test yard until 30,000 passes in 24 days.

We have not constructed an asphalt layer on SCFA base, because we'd like to observe the change of CFA base surface condition directly, and SCFA stabilized base even without a surface course is useful for a tentative pavement on a construction site. Materials and a mixing ratio for SCFA stabilized base are demonstrated in table-2 and properties of SCFA mixture at the mixing ratio are shown in table-3.

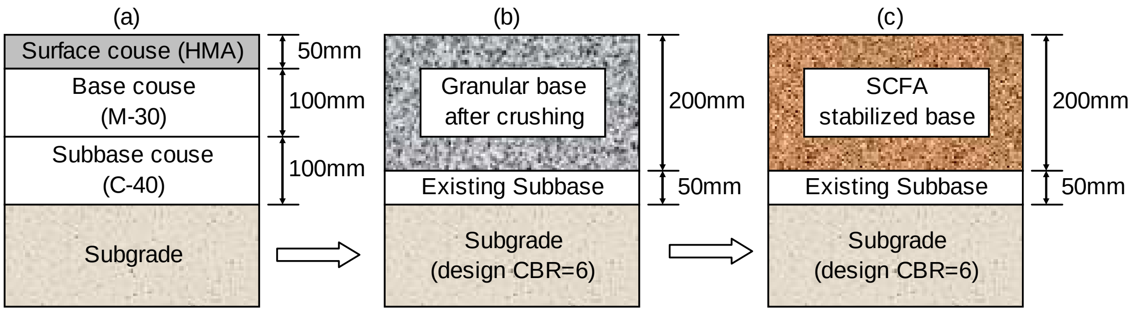

Figure-5. Pavement cross section at test yard.
((a)Existing pavement,(b)After crushing,(c)After SCFA stabilization)

Table-2. Materials and mixing ratio for SCFA stabilized base.

Item	Materials	Ratio (%)
Cement	Portland cement	2.5
Asphalt	Straight asphalt 60/80	4.0
Existing Subbase	M-30, C-40	72.4
Existing Surface couse	Dense graded asphalte concrete(13)	27.6

Table-3. Properties of SCFA mixture.

	Moisture content (%)	Dry density (g/cm^3)	Unconfined compressive strength (MPa)	Primary displacement (1/100 cm)	Residual strength rate (%)
Measurements	5.2	2.15	1.91	18	82.2
Specification	—	—	1.5～2.9	5～30	65 or more

(2) Construction view of SCFA stabilized base at test yard

Each construction view of SCFA stabilized base from spraying of slurryed-cement with Slurry Machine to the finish, is shown in Photo-4 (a)～(f). The ditches on pavement surface with scarifiers success in preventing slurryed-cement from flowing outside of the yard. We have recognized no cement scattering at all, when slurryed-cement is sprayed and SCFA base is stabilized. These demonstrate that the construction method with slurryed-cement is useful to stop cement scattering for CFA stabilization.

Photo-4. Construction view of SCFA stabilized base at test yard.
((a) Spraying of Cement slurry, (b) Sprayed pavement surface, (c) Completion of spraying,
(d) Stabilizing, (e) Leveling, (f) Finish)

(3) Evaluation of durability

In order to evaluate durability of SCFA stabilized base, we have investigated pavement surface condition and structural bearing capacity at the granular base after crushing the existing pavement and at SCFA stabilized base after 7 days curing and 30,000 times loading of the 49 kN wheel.

1) Pavement surface condition

From investigation on the surface condition of SCFA stabilized base after 30,000 times loading of the 49 kN wheel, rut depth was about 8mm and crack ratio was about 16 %. The criteria of rut depth and crack ratio for maintenance or repair at the primary road in Japan are from 30 to 40 mm and from 30 to 40 %, respectively. Both of rut depth and crack ratio are below the criteria, so we have considered that SCFA stabilized base has no problem on durability in the view of the surface condition. In the core extracted from the cracking area to observe how it is cracking after the accelerated loading test, a crack is recognized only in the range of 5 cm depth from the surface, not at the bottom of the core as shown in Photo-5. Therefore, we have determined that the crack is not due to fatigue at the bottom of SCFA stabilized base and it is a type of the longitudinal surface crack.

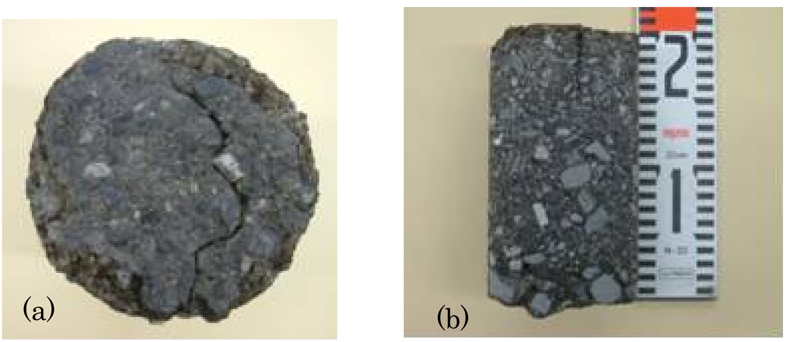

Photo-5. Example of core extracted from crack area.
((a) Surface, (b) Side)

2) Structural bearing capacity

We have conducted Falling Weight Deflectometer (FWD, shown in Photo-6) test and plate bearing test in order to evaluate structural bearing capacity of SCFA stabilized base.

a) FWD Test

FWD drops a weight to apply dynamic force onto a loading plate and measures pavement surface deflections with ten sensors from center of the loading plate to 2 m distance. Deflection curves at the same point in FWD tests (49kN loading) have changed at each stage as shown in Figure-6.

Photo-6. FWD.
((a) General view, (b) Deflection sensors)

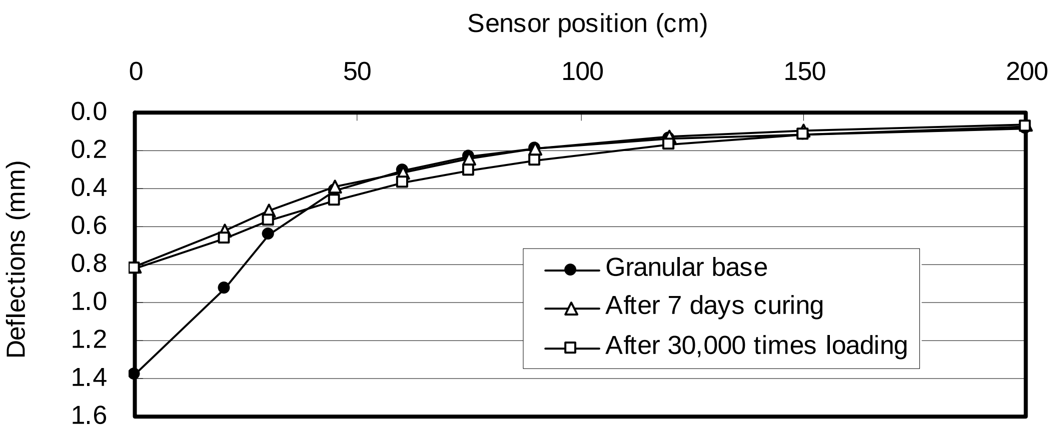

Figure-6. Deflection curve at each stage.

From Figure-6, after SCFA stabilization of the granular base, the deflection at 30 cm distant from the center of the loading plate decreases, so that bearing capacity (rigidity) of the base course is improved. The deflection curve at SCFA stabilized base after 7days curing is almost same as that after 30,000 times loading, in other words bearing capacity of SCFA stabilized base remains acceptable even after carrying design traffic volume.

We conducted back calculation at two-layer model (the base course with 25 cm thickness and subgrade) using a multi-layered elastic analytical program in order to determine the elastic modulus of each layer. Furthermore, we attempted to calculate the layer equivalent coefficient, ai of SCFA stabilized base by substituting the back-calculated elastic modulus into equation (1). Calculation results are listed in Table-4. [6]

$$a_i = 0.623 \log_{10} E - 1.095 \quad \cdots (1)[6]$$

where, a_i : layer equivalent coefficient

E : elastic modulus of base course (MPa)

Table-4. Calculation results on elastic modulus and layer equivalent coefficient of base course.

stage	Elastic modulus (MPa)		ai of base course
	Base	Subgrade	
Granular base	231.6	73.2	0.38
After 7 day curing	675.5	78.7	0.67
After 30,000 times loading	831.9	63.9	0.72

Although ai of the granular base is only 0.38, ai of SCFA stabilized base after 7 days curing increases to 0.67, which is almost same as 0.65 of CFA stabilized base shown in “the pavement design and construction guide (in February, 2006)” in Japan. That is, SCFA stabilized base with slurryed- cement has same structural bearing capacity as CFA with general powdery cement.

Besides, ai of SCFA stabilized base after 30,000 times loading is 0.72 to be larger than 0.67 after 7 days curing. This indicates that SCFA base has not been damaged significantly after the accelerated loading.

b) Plate bearing test

The result of plate bearing test is shown in Figure-7. From Figure-7, K_{30}-value of SCFA stabilized base after 7 days curing is 1.6 times larger than that of granular base, so that SCFA stabilization can enhance the base course as mentioned above from the result of FWD test. K_{30}-value after 30,000 times loading (running area) increases rather than that after 7 days curing before acceleration loading, and is about two times as large as that of the granular base.

By the way, when K_{30}-value at the loading area after 30,000 times loading is compared with that at the non-loading area , the former is larger than the latter. This suggests the repetition of loading could additionally compact to strengthen the pavement including SCFA stabilized base at the loading area.

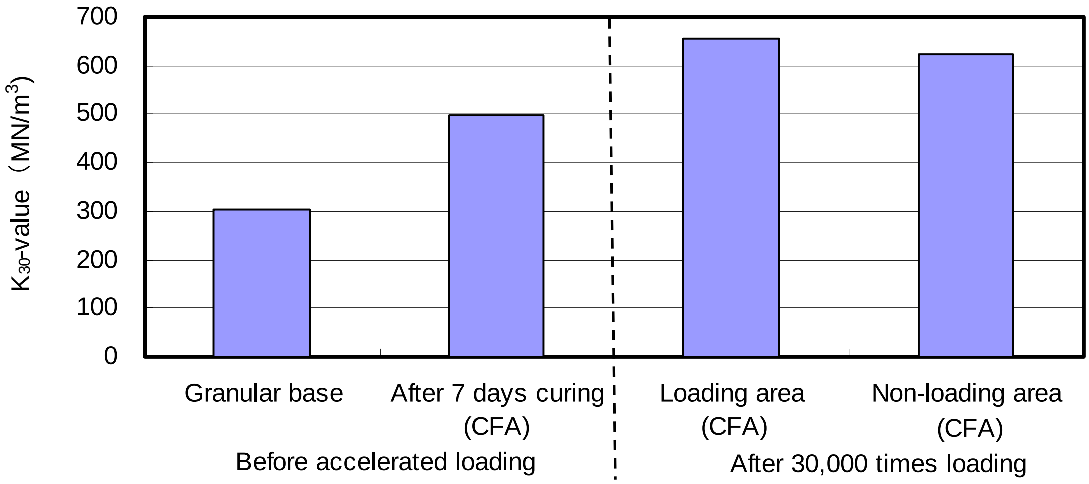

Figure-7. Plate bearing test result.

3. CONCLUSIONS

The knowledge from this research is summarized as following.

(1) In order to stop cement scattering at spreading and mixing of cement, we have invented SCFA (Slurryed-Cement Foamed-Asphalt) stabilized base with cement slurry and confirmed that workable time of slurryed-cement and SCFA stabilized base is longer than the construction time necessary for CFA stabilization of an existing pavement. After that, when constructed at accelerated test yard with Slurry Machine newly developed to spray slurryed-cement, SCFA stabilized base can stop cement scattering absolutely.

(2) We have evaluated structural bearing capacity of SCFA stabilized base with FWD after 7 days curing. As the result, the layer equivalent coefficient of SCFA stabilized base with slurryed-cement mostly agrees with that with general powdery cement (0.65). In other words, SCFA stabilized base has the same bearing capacity as CFA stabilized base.

(3) After the accelerated loading test (30,000 times loading of 49 kN wheel), SCFA stabilized base keeps good surface condition and bearing capacity, so that it has durability enough to the design traffic volume.

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